RESEARCH DEPARTMENT

Differential fading of television sound and vision signals at u.h.f.

RESEARCH REPORT No. K-183

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THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

RESEARCH DEPARTMENT

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for Head of Research Department

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SUMMARY

When receiving television signals at a translator relay station, for re-transmission after frequency changing, a common amplifier for sound and vision signals is usually employed. Thus the power ratio of the re-transmitted signals is the same as that received from the parent station. Differential fading of the sound and vision signals is therefore important, inasmuch as it would affect this ratio.

This report describes an investigation carried out to assess the probability of occurrence of such differential fading. It is deduced that the effect is of little practical significance. A more important requirement at relay stations distant from the parent station is the provision of an adequate range of automatic gain control, to compensate for the fading range of the sound and vision signals.

1. INTRODUCTION

Propagation characteristics at u.h.f. are such that a very large number of relay transmitters, of differing powers, will be required to provide adequate coverage of the United Kingdom. It is proposed that where possible these relay stations should be of the "translator" type, where the parent transmission is received, amplified, and re-transmitted from the same site in a different frequency channel. A considerable saving in cost may be obtained, particularly in the higher power stations which require klystron or travelling-wave tube output stages, if common amplification of sound and vision signals is adopted. Furthermore, by avoiding the use of the filter circuits associated with separation of sound and vision signals, group delay distortion (of particular importance in colour transmission) will be much reduced.

This principle of common amplification at an intermediate frequency is inherent in the conception of the translator type of u.h.f. relay station. It does, however, imply the use of a common automatic gain control (a.g.c.) for both sound and vision transmissions. Consequently, if differential fading between the received sound and vision signals occurs, no compensatory correction can be applied to restore the correct ratio to the transmitted signal. This condition is obviously undesirable and an investigation was carried out to assess the probability of occurrence of differential fading of sound and vision transmissions over path lengths representative of those between parent and relay stations.

2. FACTORS AFFECTING CHOICE OF RECEIVING SITES

Relay stations will generally be situated at distances between 10 km and 100 km from the parent station. It is possible that special circumstances may require reception at distances exceeding 100 km, e.g. to provide a service to the Shetland and Channel Islands. However it is expected that relay stations at these distances will generally require separate receiving and transmitting sites, and thus will not be of the translator type. It is probable that the great majority of relay stations will be within 50 km of the parent transmitter.

Experience of reception within the Crystal Palace service area has shown no evidence of significant fading at distances less than 50 km. Three receiving sites were therefore selected to investigate fading characteristics within the range 50 km to 100 km of the parent transmitter.

3. SITES AND RECORDING EQUIPMENT

3.1. Transmitting Site

The site details and transmission characteristics of the Crystal Palace transmitter are given in Table 1.

The measurements were normalized for 1 kW effective radiated power (e.r.p.) on vision and sound channels, assuming a peak vision e.r.p. of 320 kW

(25 dB relative to 1 kW) and a vision-to-sound power ratio of 7 dB.

3.2. Receiving Sites

The receiving sites chosen were the BBC monitoring station at Caversham, Berks., the Police Wireless Station at Mursley, Bucks., and the BBC transmitting station at Manningtree, Essex. Site details are given in Table 2, and their geographical positions represented in Fig. 1. The profiles for the transmission paths are shown in Fig. 2.

As will be seen from Table 2, measurements at Manningtree were made at two receiving aerial heights. These two series of measurements were made over consecutive periods of time, of which the first period (with the aerial at 9 m a.g.l.) corresponded with the measurement periods at Caversham and Mursley.

The path profiles of Fig. 2 indicate that the path to Caversham is unobstructed, and the paths to Mursley and to the higher aerial at Manningtree involve single diffractions. The transmission path profile for the low aerial condition at Manningtree has one principal obstruction together with a number of points involving grazing incidence at the receiving end of the path.

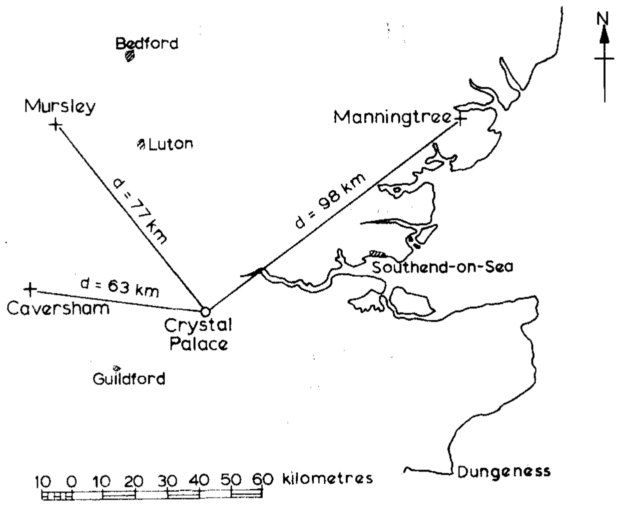


Fig. 1 - Geographical distribution of transmitting and receiving sites

o Transmitting site + Receiving site

TABLE 1

Crystal Palace Transmitting Site Details

CHANNEL NO.	FREQUENCY MHz VISION	FREQUENCY MHz SOUND	POLARIZATION	SITE HEIGHT a.m.s.l. (m)	AERIAL HEIGHT a.g.l. (m)	LATITUDE	LONGITUDE
33	567·25	573·25	Horizontal	110	193	51°25′20″N	00°04′17″W

TABLE 2

Receiving Site Details

RECEIVING STATION	PATH LENGTH (km)	SITE HEIGHT a.m.s.l (m)	TRUE BEARING TO TRANSMITTER	RECEIVING AERIAL GAIN (dB rel. to $\lambda/2$ dipole)	LATITUDE	LONGITUDE	APPROX. RECEIVING AERIAL HEIGHT a.g.l. (m)	DURATION OF RECEIVING PERIOD (days)
Caversham	63	82	95°	6·5	51°28′52″N	00°57′23″W	11	180
Mursley	77	158	140°	6·5	51°57′12″N	00°48′05″W	9	223
Manningtree	98	36	236°	10	51°55′25″N	01°05′20″E	9	142
Manningtree	98	36	236°	10	51°55′25″N	01°05′20″E	75	104

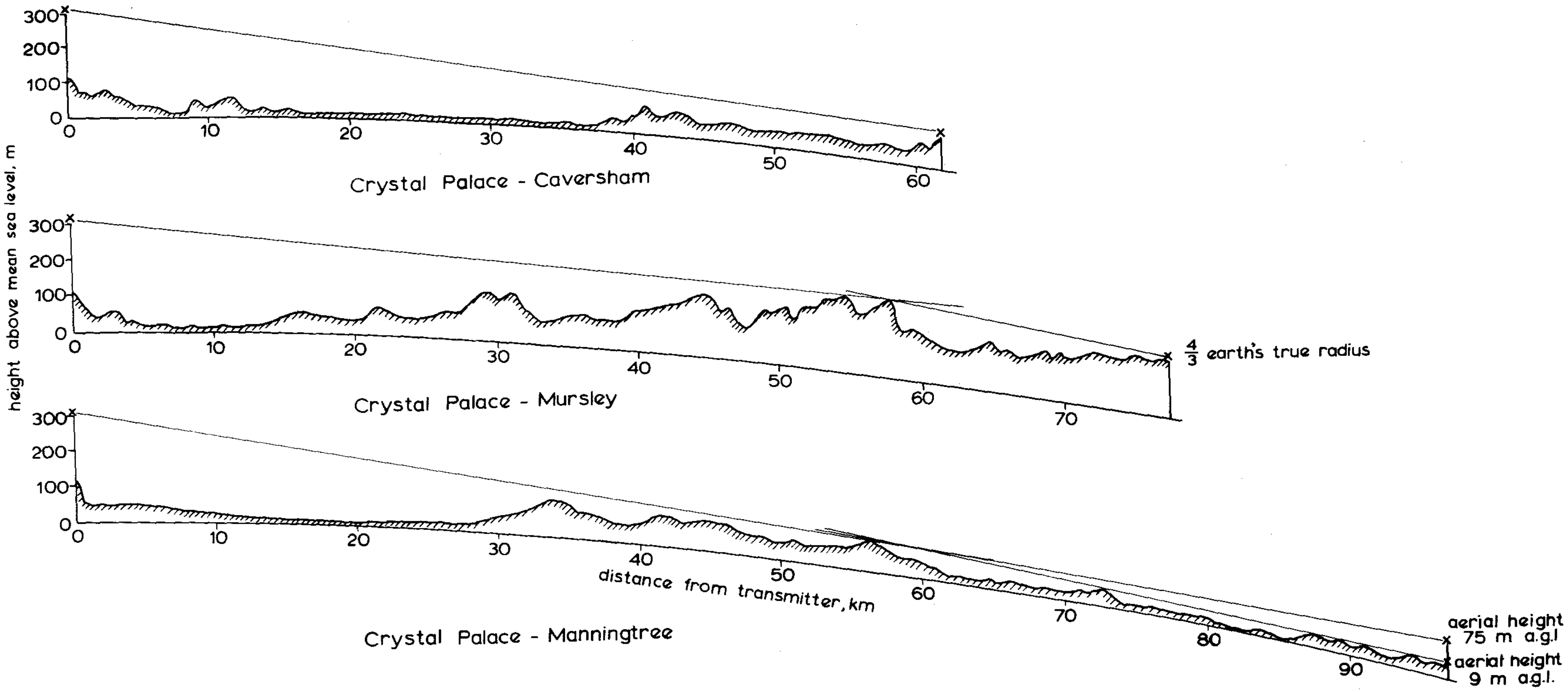


Fig. 2 - Path profiles from transmitter to receiving sites

3.3. Equipment

3.3.1. Receivers and Recording Equipment

The receivers used for these measurements were of the type described in a previous Research Department report[1] having a nominal bandwidth of ±60 kHz. Two receivers, tuned respectively to sound and vision carrier frequencies, were installed at each site and fed from a common receiving aerial. The vision receiver output was proportional to the mean level of the vision carrier, and consequently the ratio between the two receiver outputs varied according to the picture content. This limited the accuracy of the comparisons between channels, since it was not generally possible to dissociate differential fading from variations due to changes in picture content, unless the differential effects exceeded ±2 dB.

The outputs from sound and vision receivers were individually recorded and were also fed into a "difference" amplifier the output of which was also recorded. This output varied about an arbitrary zero, representing the normal vision-to-sound power ratio.

Recorder chart speeds used were 25 mm (1 in.) per hour at Caversham and Mursley, and 50 mm (2 in.) per hour at Manningtree.

3.3.2. Transmitter Output Power Monitor

The two transmitters at Crystal Palace were monitored to give recordings proportional to sound output power, and also to both peak and mean vision output powers. This monitoring facility was obtained by combining the outputs from two probes inserted in the aerial feeders. This combined output was then separated by a filter into sound and vision components, which were amplified and recorded. A schematic of this arrangement is represented in Fig. 3.

4. RESULTS

4.1. Fading Characteristics of the Sound Transmissions

Before considering the probability of occurrence of differential fading between sound and vision channels it is appropriate first to consider the fading characteristics of the individual channels

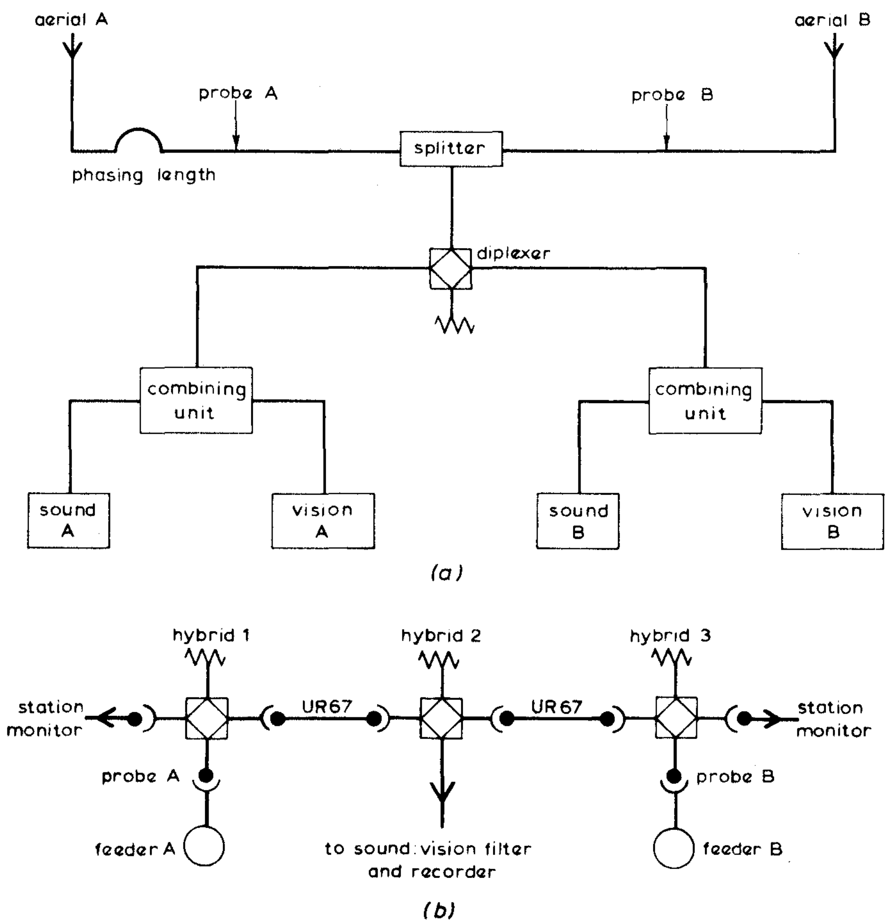


Fig. 3 - Crystal Palace: u.h.f. output level monitor
(*a*) Location of probe points (*b*) Method of combining probe outputs

TABLE 3

Sound-Channel Field-Strength Measurements

RECEIVING STATION	RECEIVING AERIAL HEIGHT a.g.l. (m)	FIELD STRENGTH [dB(μV/m)] FOR 1 kW e.r.p. EXCEEDED FOR THE FOLLOWING PERCENTAGES OF TIME						
		0·1	1	10	50	90	99	99·9
Caversham	11	45·0	42·0	41·0	40·0	39·0	37·0	35·5
Mursley	9	58·0	51·0	46·5	45·0	43·0	42·0	40·0
Manningtree	9	59·5	55·5	41·0	33·0	30·5	26·0	15·0
Manningtree	75	72·5	66·0	57·0	52·5	49·5	45·0	37·0

at the various receiving sites. The sound-channel measurements were analysed to determine the length of time for which signal levels exceeded various values of field strength. These time durations, expressed as percentages of the overall valid recording time were then plotted against field strength, normalized for an e.r.p. of 1 kW. The resultant field-strength/time-percentage distributions are represented in Fig. 4, and the field strength values exceeded for selected time-percentages, derived from this figure, are listed in Table 3.

At this stage it may be explained why two series of measurements were made at Manningtree. The first series of measurements, at an aerial height of 9 m a.g.l. resulted in a median field strength of 33 dB(μV/m) for 1 kW e.r.p. This would be equivalent to a field strength of not more than 63 dB(μV/m) for the highest transmitter e.r.p. (1 MW) envisaged for use in the United Kingdom, and as such would be inadequate for normal translator operation. Consequently, to simulate more closely probable translator reception conditions at this range, a further series of measurements were made at a receiving aerial height of 75 m a.g.l.

4.2. Comparison between Fading Characteristics of Sound and Vision Channels

The most explicit method of presenting the results of differential fading comparisons would be in terms of a probability relationship, specifying the deviation from the nominal vision-to-sound power ratio in terms of the percentage of time for which this deviation is exceeded. This relationship is, however, not obtainable for the following reasons:

(a) As previously discussed, the use of receivers responding to mean vision output power limited the accuracy of the minimum observable deviation due to propagation effects.

(b) The characteristics inherent in the nature of differential fading are such that accurate assessment of fading duration requires the use of impracticably high recorder speeds.

(c) The "difference" recording, although extremely useful in exhibiting the time relationship between fast fading of the individual signals, suffered from inaccuracies associated with transient effects in the receiving apparatus. Consequently the deviation shown on the chart depended not only upon the magnitude of the change in ratio, but also upon the rate of change. In the sections of chart contained in Figs. 5 to 11 the ordinate scale refers to the "steady-state" deviation.

In view of these difficulties it appeared appropriate to present the results of the investigation in the form of a general discussion illustrated by suitable examples of the recordings obtained. Examples of these recordings are reproduced in Figs. 5 to 11. The ordinate scales of the vision and sound recordings represented in these figures are logarithmic, the signal levels being expressed in dB relative to 1 μV/m for 1 kW e.r.p. Where appropriate a subsidiary ordinate scale relates the sound channel field strength to the percentage of the total recording time for which it is exceeded. This information is derived from Fig. 4.

5. DISCUSSION OF RESULTS

5.1. Results of Caversham Measurements

The median sound-channel field strength at this site is only 40 dB(μV/m) for 1 kW e.r.p., although survey measurements made in the vicinity of the Caversham site indicate an ambient field strength of 55 dB(μV/m) for this e.r.p. The low field strength at the chosen receiving site is considered as being entirely due to the location of the aerial, which is screened by several densely-foliated trees. On windy days, the presence of these trees caused a rapid "flutter" of received signal, the variations being uncorrelated on sound and vision

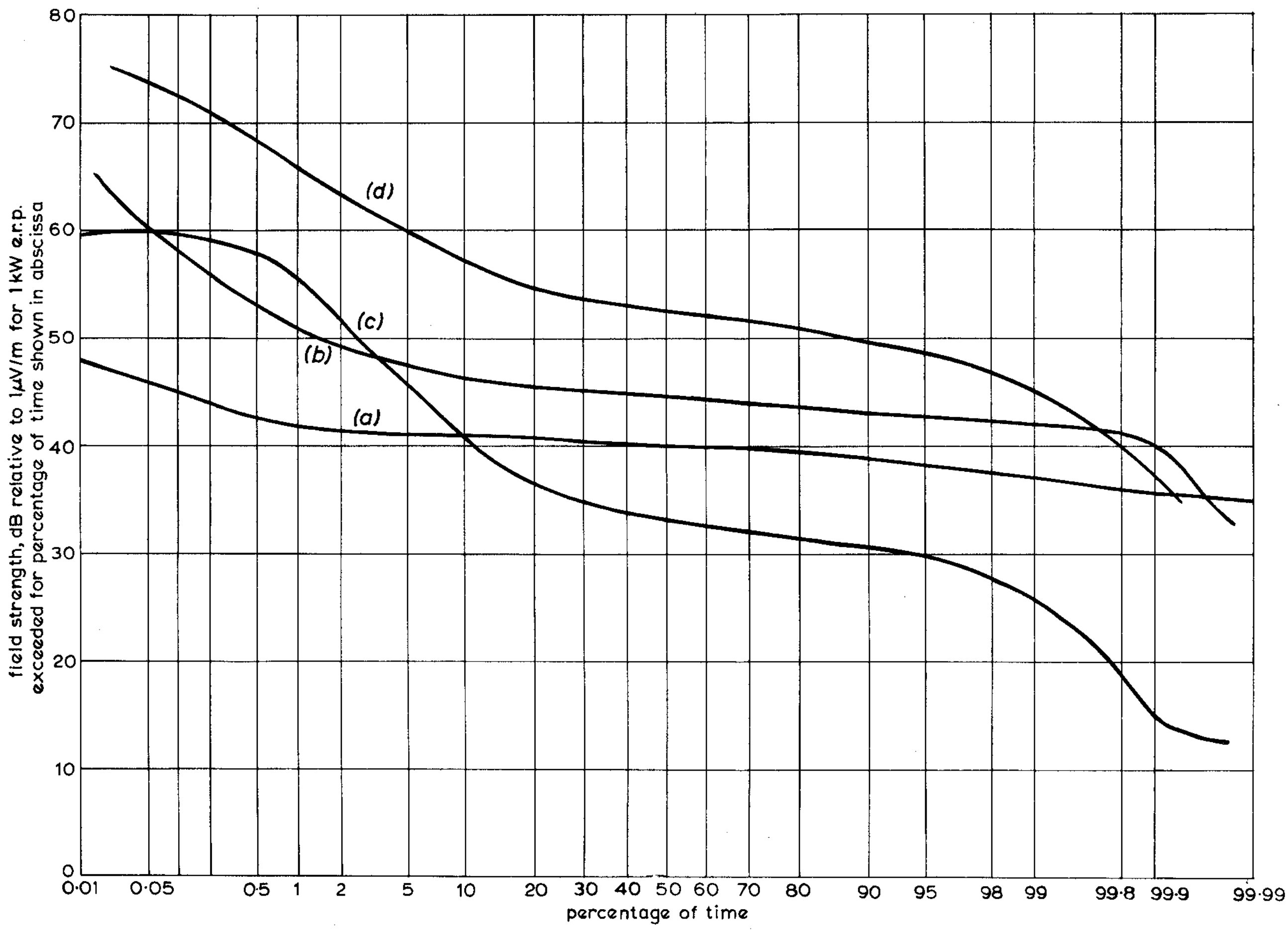


Fig. 4 - Variation of sound channel field strength with time

	RECEIVING SITE	PATH LENGTH km	Rx.Ae. Ht.(m) a.g.l.
(*a*)	Caversham	63	11
(*b*)	Mursley	77	9
(*c*)	Manningtree	98	9
(*d*)	Manningtree	98	75

channels. The most pronounced example of this effect is represented in Fig. 5, in which, however, the vision-to-sound power ratio variation seldom exceeds ±2 dB. This type of fading induced by by localized effects is considered to be of little relevance to u.h.f. relay stations, since it should normally be possible to mount receiving aerials well clear of surrounding trees.

In Fig. 6 are represented recordings obtained at Caversham and Mursley during the evening of 1st April 1965. This period provided the most severe fading encountered at these sites. It can be seen from the Caversham recordings, that after allowance has been made for variations in picture content on the vision channel, there is no evidence of differential fading. The most obvious discrepancy (at A in Fig. 7) between sound and vision signals received at Caversham is represented in Fig. 7. In view of the unusual nature of the recording trace in this instance, and as there was no fading at the more distant site of Mursley, it is by no means certain that this is a genuine propagational effect rather than being due to gain variations in the recording receiver.

5.2. Results of Mursley Measurements

As already mentioned, Fig. 6 represents the most severe fading encountered at this site. Although the fading range of the individual channels is of the order of 50 dB, the difference record shows a deviation greater than ±2 dB for only 8 minutes. A deviation greater than ±4 dB is exceeded only on some four occasions, each of a duration of a fraction of a minute.* Other periods of deep fading were recorded on about five days during the measurement period.

* The spikes at 2 minute intervals on this record are caused by locally generated interference.

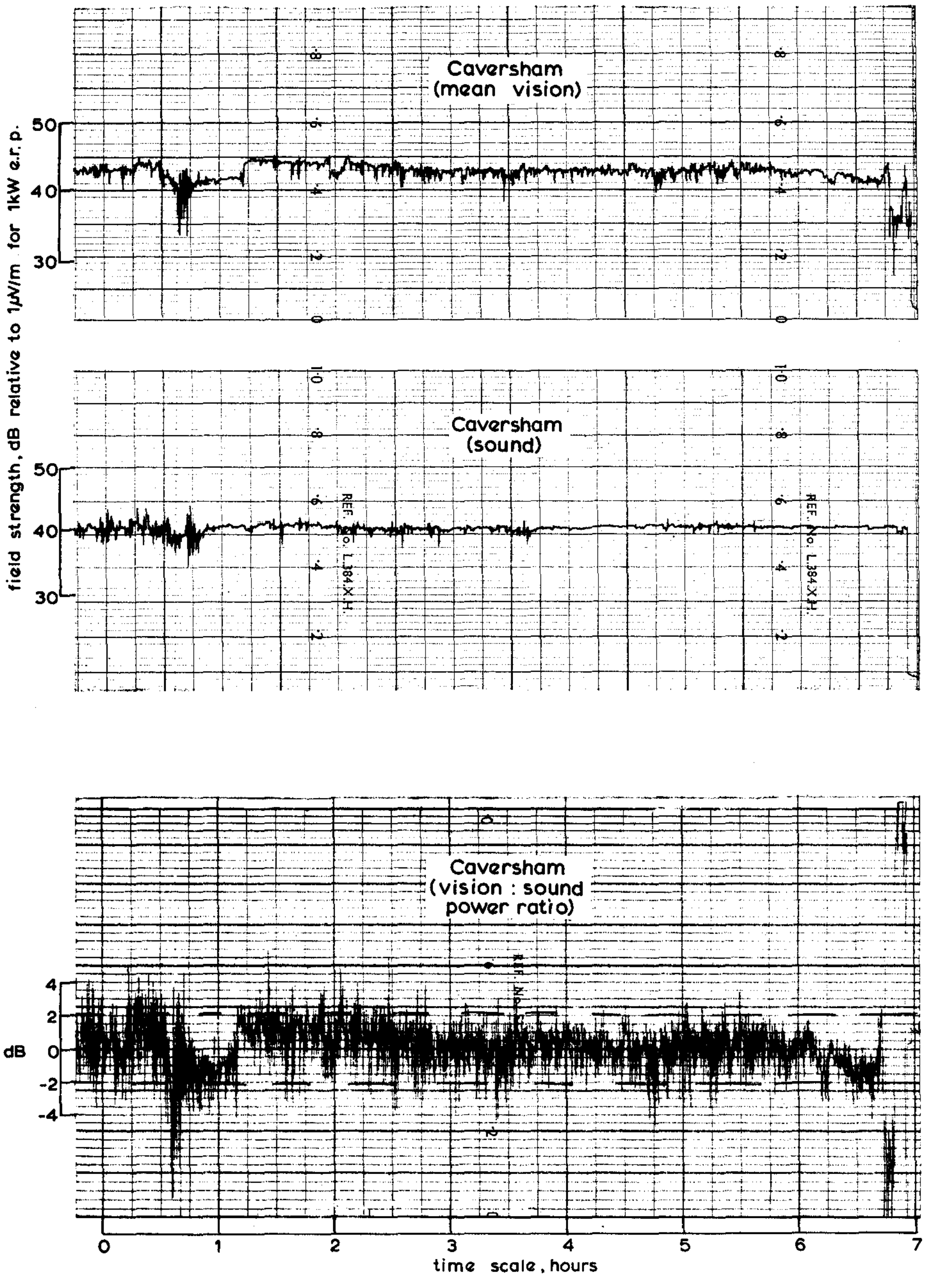


Fig. 5 - Example of signal fluctuations at Caversham resulting from wind in local foliage

The overall period of severe disturbance involved less than 10 hours throughout the 223 days of recorded transmission, and the duration of the deep fades ("drop-outs") which gave rise to differential effects represented only a small proportion of this 10 hours. Differential fading does not therefore appear to be significant at this distance. A more important requirement is the provision of an adequate range of a.g.c. to compensate for the individual signal enhancements, which exceed 13 dB for 0·1% of the time.

5.3. Results of Manningtree Measurements

5.3.1. Recordings with Receiving Aerial at 9 m a.g.l.

As previously discussed, the received signal at this site and aerial height would be inadequate for translator operations. However the records are of interest as they demonstrate two types of propagation characteristic giving rise to differential effects. These are typically represented by the records represented in Figs. 7 to 9, of which Figs. 7 and 8 show comparative fading ranges at the three receiving sites.

From the record for 7th October 1965 reproduced in Fig. 9 it may be seen that the first part of the day comprised a period of pronounced abnormality giving considerable variations in received field strength. There is, however, little differential fading except for two occasions involving "drop-outs" of sound or vision carriers. This period is followed by another in which the mean signal level corresponds to the value for normal propagation, but is characterized by fast fading of small amplitude.

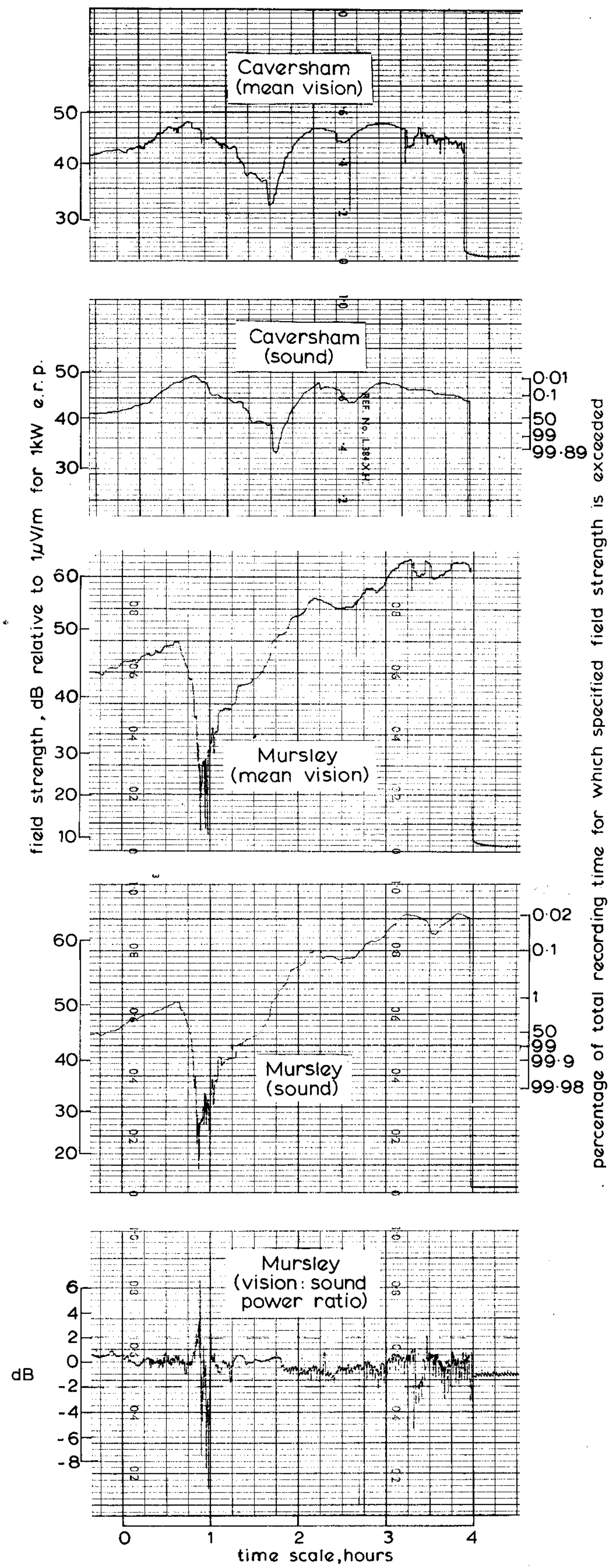


Fig. 6 - Comparison of recordings made at Caversham and Mursley during a period of severe propagation abnormality

These fades are uncorrelated on sound and vision channels and consequently considerable deviations are shown on the difference record. The final period of the day again represents a condition of severely abnormal propagation with numerous "drop-outs".

5.3.2. Recordings with Receiving Aerial at 75 m a.g.l.

The results of 104 days of recording at this aerial height are classified in Table 4 in terms of the maximum deviation of the sound-channel field strength from the overall median value.

TABLE 4

Classification of Diurnal Fading Range
Site: Manningtree
Receiving Aerial Height 75 m a.g.l.

CLASS	MAXIMUM DEVIATION FROM MEDIAN (dB)	NO. OF DAYS	% OF TOTAL NO. OF DAYS
1	≯ ± 2	48	46·2
2	≯ ± 4	66	63·5
3	≯ ± 8	80	76·8
4	≯ ±16	97	93·3
5	Exceptional days (see Table 5)	8	7·7

On only one occasion during the days comprising Classes 1 to 4, i.e. those days for which the fading range did not exceed ±16 dB, was there any evidence of differential fading. The results of this day and of the remaining days are summarized in Table 5, and the recordings obtained on two of these days are reproduced in Figs. 10 and 11.

The record for 17th December 1965 is not reproduced, but it indicates differential fading between vision and sound signals during a day when the overall fading range of either channel was only 4 dB. Although the Crystal Palace monitor charts gave no indication of output variations it is by no means certain that this is a true propagation phenomenon. The variation of vision-to-sound power ratio was however only 2 dB, which as discussed earlier is the minimum that can be identified with the recording equipment used.

Over the other exceptional days the total period involving the deep fading associated with differential effects amounts to some 7¾ hours, representing approximately 0·5% of the total recorded time. The actual duration of differential fading is only a small proportion of this 7¾ hours.

TABLE 5

Occurrence of Exceptional Propagation Conditions at Manningtree

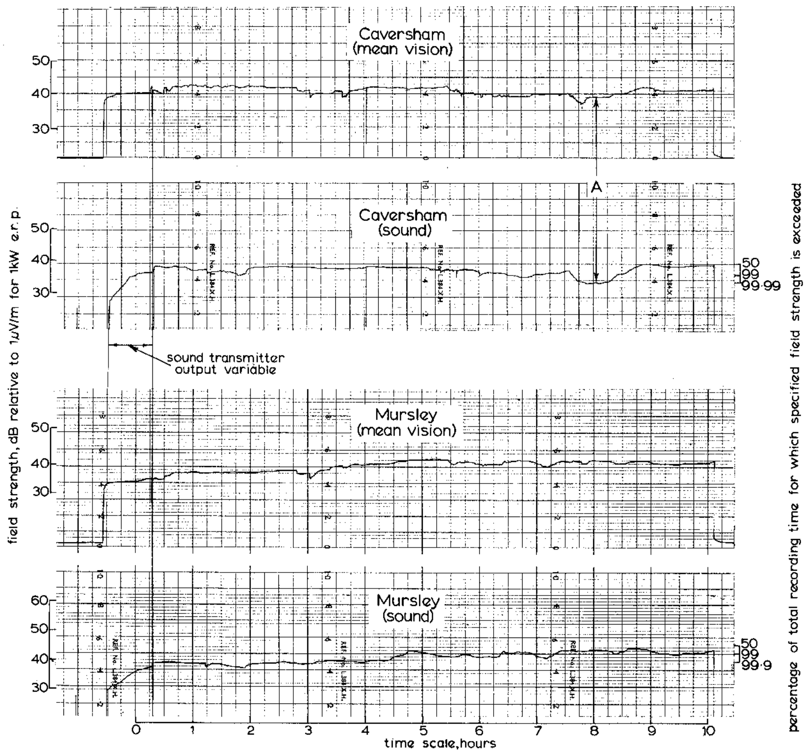
DAY	DATE	OVERALL FADING RANGE (dB)	REMARKS
1	22.10.65	>35	Deep fading. "Drop-outs" over a period of ½ hour
2	25.10.65	>40	Deep fading. "Drop-outs" over three periods totalling 1 hour
3	26.10.65	>30	No deep fading or differential effects.
4	17.12.65	4 (sound only)	Low field strengths all day, but sound field strength falls slowly by 2 dB relative to vision.
5	5. 1.66	35	Deep fading. "Drop-outs" over a period of ½ hour.
6	6. 1.66	>30	Deep fading over four periods totalling 1½ hours
7	7. 1.66	30	Represented in Fig. 10. Deep fading on a number of occasions totalling approximately 4 hours.
8	8. 1.66	>40	Represented in Fig. 11. Single period of deep fading lasting ¼ hour.

5.3.3. Comparison of Measurements at Receiving Aerial Heights of 9 m and 75 m a.g.l.

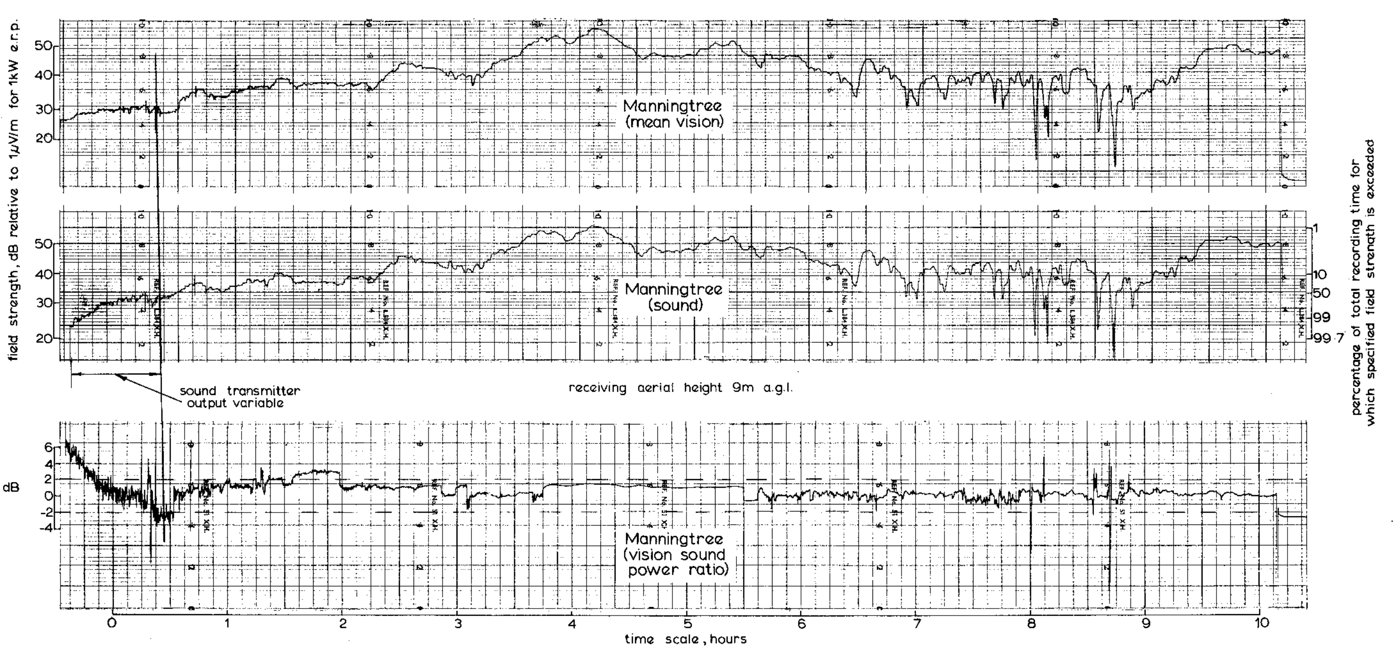
It is of interest to compare the results of the measurements obtained at the two receiving aerial heights at Manningtree. From the field-strength/time-percentage distributions of Fig. 4 it may be seen that at any specified time percentage in excess of about 20, the ratio between the field strengths received at the two aerial heights is virtually constant and equal to approximately 19 dB. At smaller percentages of time this ratio is progressively reduced to a minimum of about 10 dB at 0·5% to 1% of the time.*

Although it may be unwise to generalize from this one result it does imply that the range of fading, (particularly with respect to signal enhancement above the median value) is a function not only of distance from the parent station, but also of the nature of the transmission path. For planning purposes this fact is acknowledged by the C.C.I.R.[2], the effective length of the transmission path being modified according to the height above mean terrain of the receiving aerial.

* For still smaller percentages the ratio again increases. This is not thought to be significant since the measurements were not concurrent, and thus it is unlikely that the extremities of the fading characteristics will be directly comparable.



(a)



(b)

Fig. 7 - Comparison of recordings for 22nd August 1965 showing anomalous fading of the received sound signal at Caversham

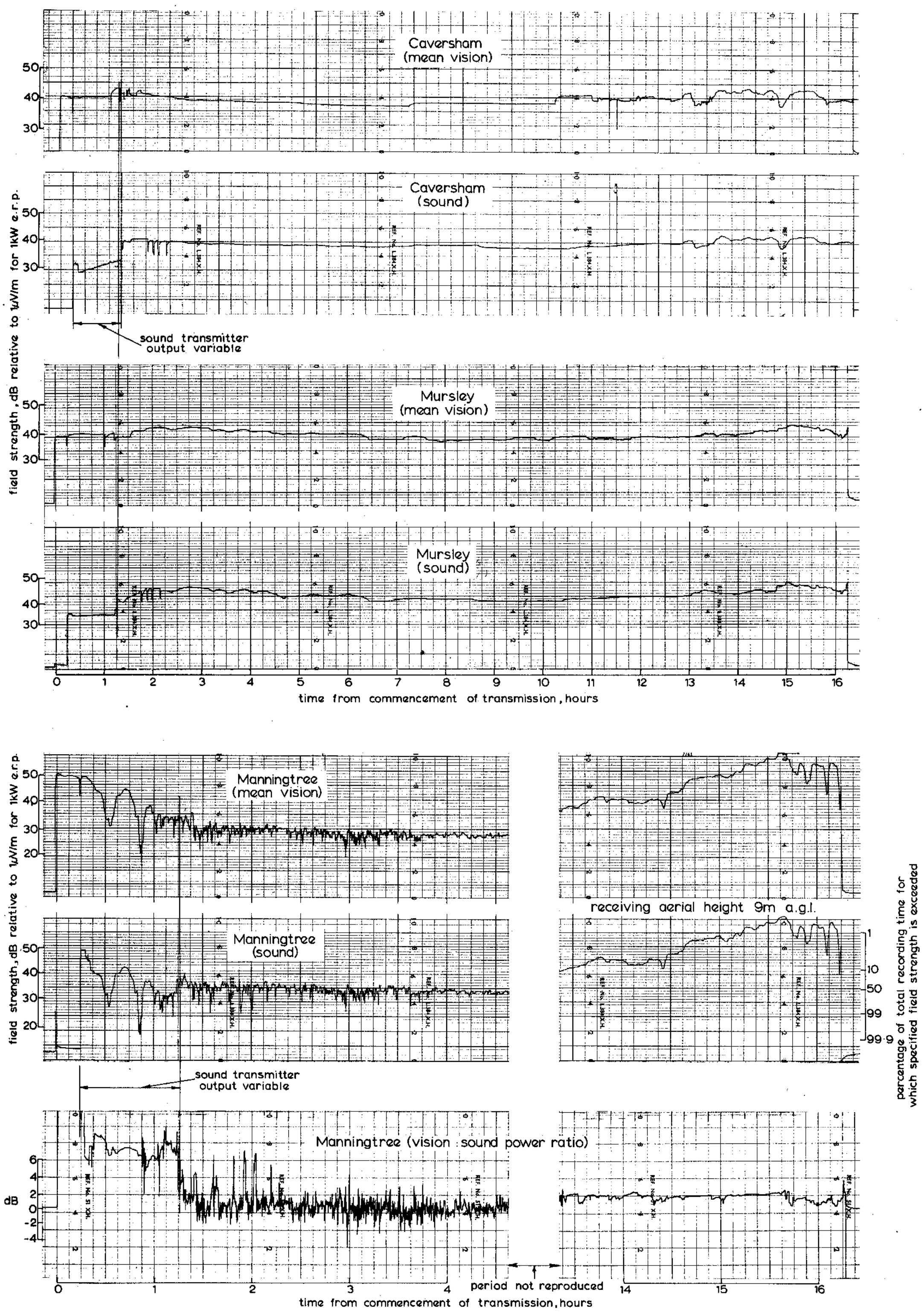


Fig. 8 - Comparison of recordings for 14th August 1965 showing typical fading characteristics during abnormal propagation conditions

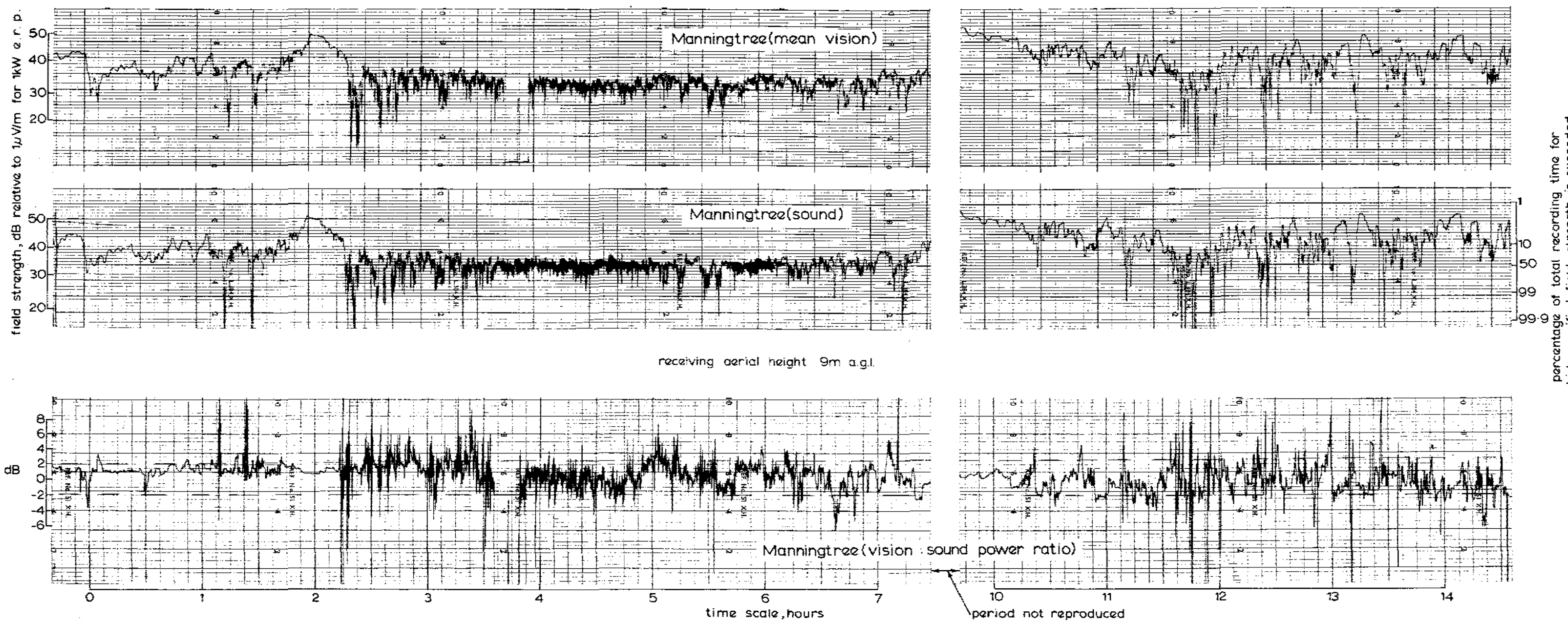


Fig. 9 - Example of differing fading characteristics recorded at Manningtree on 7th October 1965 with receiving aerial height of 9 m a.g.l.

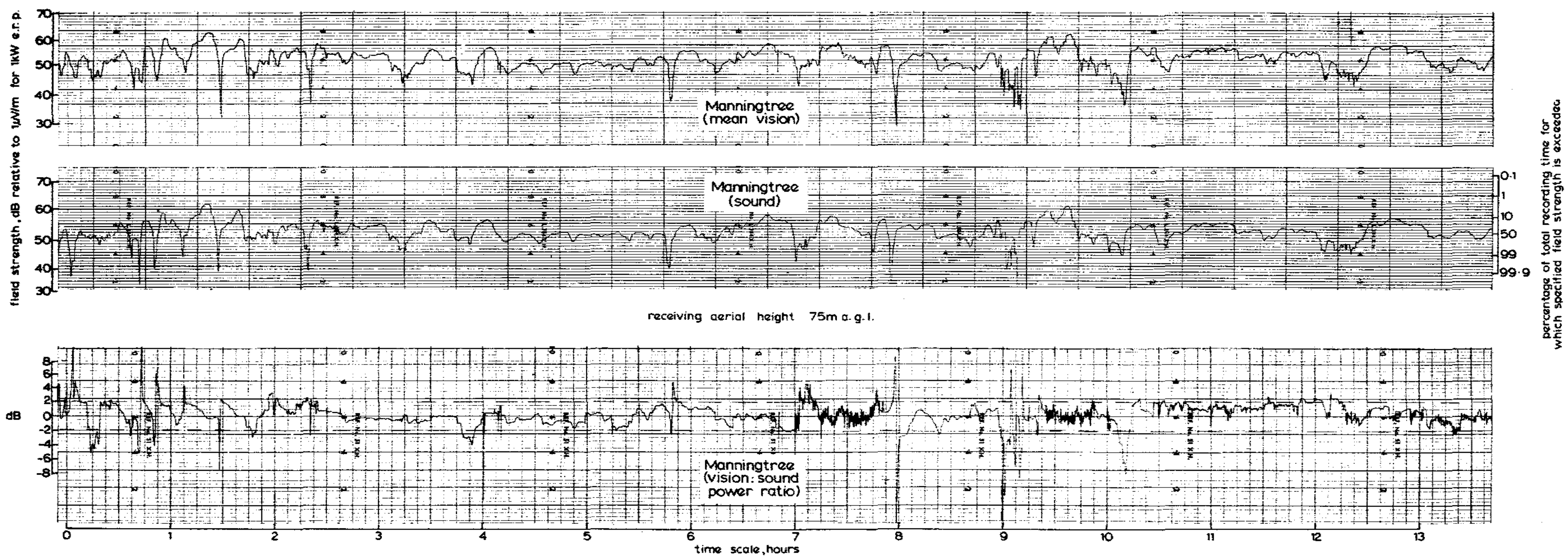


Fig. 10 - Example of severe fading recorded at Manningtree on 7th January 1966 with receiving aerial height of 75 m a.g.l.

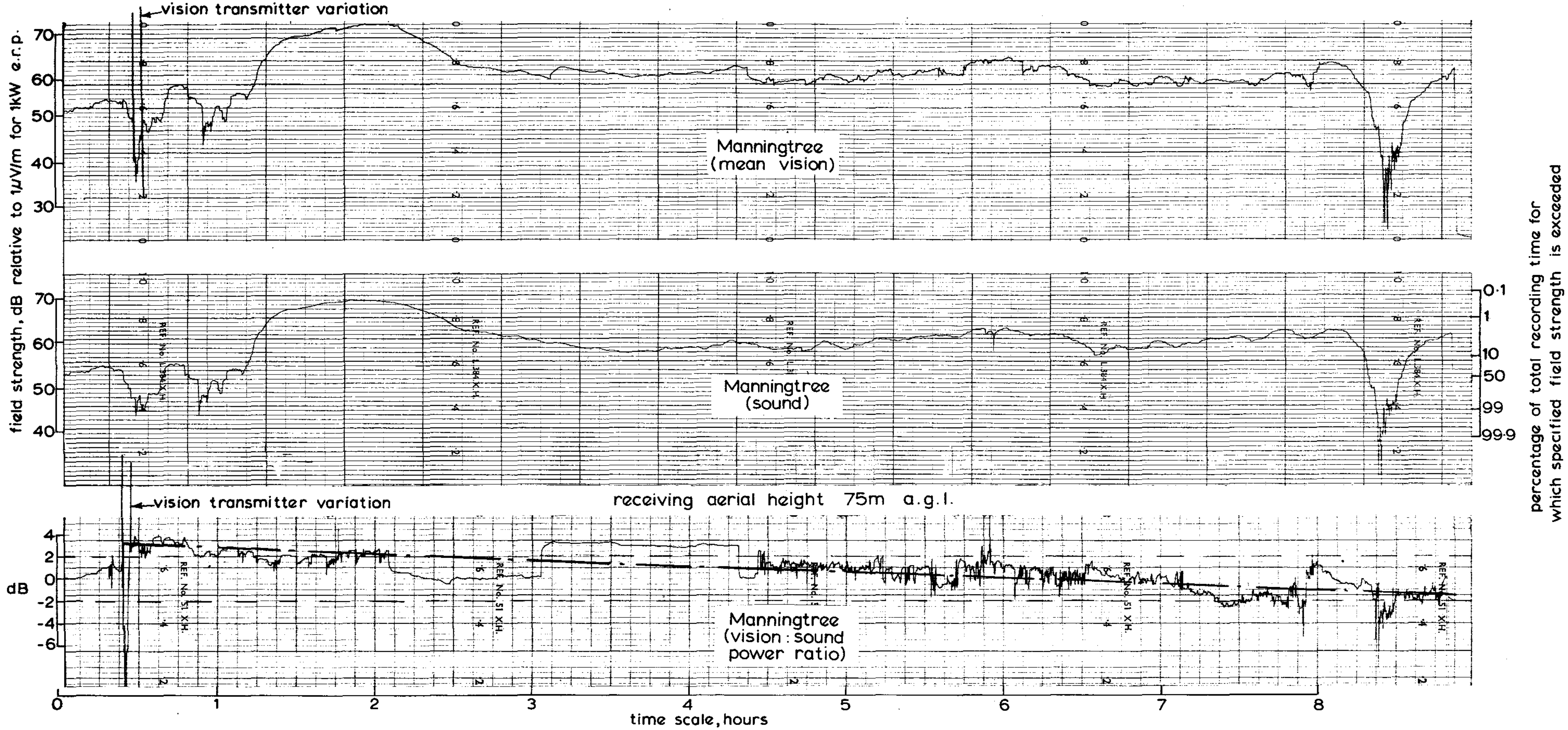


Fig. 11 - Example of abnormal propagation recorded at Manningtree on 8th January 1966 with receiving aerial height of 75 m a.g.l.

——-·——-·—— *Recording shows a prolonged enhancement followed by a single deep fade*

6. CONCLUSIONS

(i) Differential fading of sound and vision signals over path lengths less than 100 km only occurs during exceptional propagation conditions associated with deep fades or "drop-outs" of the individual signals. These conditions were never observed at the nearest site (Caversham) and rarely at the intermediate site (Mursley). At the farthest site (Manningtree) the conditions for differential fading occurred relatively often when the receiving aerial height was low. However this situation was not typical of practical reception conditions, since the field strengths were inadequate for translator operation. With the aerial height increased sufficiently to provide re-broadcast reception, conditions giving rise to differential fading occurred for some 0·5% of the total time.

(ii) Since differential fading is associated primarily with "drop-outs" of sound or vision signals, the effect will be of little importance since the service will in any case be virtually lost over the period of the "drop-out". The range of fading of the received signals under these conditions is likely to be beyond the capabilities of practical automatic gain control circuits.

(iii) It is understood that existing translator designs utilize an a.g.c. giving an output variation less than ±1 dB over an input range of ±10 dB. Referring to Fig. 4 it may be seen that even at only 77 km from the transmitter the field strength exceeds the median value by more than 10 dB for 0·3% of the time. At 98 km (and receiving aerial height = 75 m) this value of enhancement is exceeded for 2·5% of the time. These values are comparable with the results of earlier measurements[3,4] over equivalent path lengths. These indicated signal enhancements exceeding 10 dB above the median value for 1% and 1·5% of the time over respective path lengths of 85 km and 100 km. It would therefore appear advisable to provide translators with an a.g.c. range adequate to compensate for signal enhancements in excess of 10 dB above the median value at sites more than 70 km from the parent station. It is not however expected that many translator relay stations will be required at such distances.

(iv) This investigation has considered only differential effects due to abnormalities affecting the propagation path. It should be remembered that the translator will also be affected by other, more predictable, differential effects when sound or vision transmitters of the parent station are operating under reduced power conditions. In this context it is appropriate to mention transmitter output stability. Fig. 11 shows a gradual reduction of vision-to-sound power ratio throughout the period of the recording. The range of the variation is at least 3 dB, and both peak- and mean-power vision monitor charts at Crystal Palace confirm it as being due to a decay of vision output power.

7. ACKNOWLEDGEMENTS

The BBC acknowledges with thanks the site facilities given at Mursley by the Buckinghamshire County Constabulary.

Thanks are also due to the Engineers-in-Charge and their staffs, at the BBC Monitoring Station, Caversham, and at Crystal Palace, for the routine checking of recording equipment which was carried out on our behalf.

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